Exploring core muscle stability impact on trunk control and energy cost of walking in stroke patient

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Chapter 01

Introduction

1.1 Overview of stroke

Stroke is a disease characterized by acute disruption of brain functions arising from a serious distortion of the blood flow to the brain. Interruptions of the flow of blood may result in several scenarios such as blocks or tears that cause hemorrhages. Severe effects may lead to permanent damage from neurologic stroke which would cause serious disabilities of enormous extent that reach other domains, such as mobility or speech or cognitive functions, of the patients. According to WHO stroke represents the abrupt onset clinical symptoms either indicating focal and global disturbances in the brain's cerebral function. They often last more than 24 hours or are fatal. Other causes are ruled out; they are usually due to vascular causes. Such attacks of stroke can severely impact patients, their family, and caregivers in regard to rehabilitation and adapting to a new physical disability. Permanent brain damage may be caused by stroke; thus, this is an emergency condition that requires immediate medical attention. Being one of the most common causes of disability and death worldwide, stroke continues to be a major public health issue that requires continuous research to identify effective prevention, treatment, and rehabilitation measures to prevent the impact of stroke on affected individuals and society as a whole. In fact, only by understanding the complexities inherent to stroke can an integrated approach of providing comprehensive healthcare be developed to cover the immediate and long-term processes of recovery, finally to improve the quality of life of a patient after a stroke

. The terms "premature stroke," "early-onset stroke," and "stroke among the young/young stroke" have been used interchangeably in the current literature. Perhaps it is because there isn't a firm definition of what constitutes a premature stroke. Neither are "young" or "juvenile" ages defined consistently. While the lower age cut-point is fairly uniform at 18 years, upper limits range over the decade between 45 and 55 years of age, with 45 and 50 representing the most frequently selected cut-points. These cut-points lie below the critical age of 55, after which stroke incidence doubles for each advancing decade of age. Besides,

they lie within the lower quartile of the total distribution of stroke age whose median ranges around 60 to 65 years. To make a more all-inclusive account we'll discuss this matter in relation to the bigger age bracket of 18-55, that covers most of the relevant literature.(1)

1.2 Importance of mobility in stroke rehabilitation

Mobility is a very essential aspect of stroke rehabilitation. It makes up an essential element in restoring independence and general quality of life for survivors of stroke. Generally, a stroke is characterized by gross impairment of movement, muscle strength, and coordination, thereby causing significant inability of the patient to perform his/her normal daily activities. Restoration of mobility is thus brought about by interventions in rehabilitation programs through physical therapy, strength training, and functional exercises.

Improved mobility correlates directly with the ability to perform self-care activities and, consequently, with overall psychological wellbeing and support independence. Although core stability training is expected to offer adequate trunk training, evidence for using it in stroke is mostly lacking. Since innervations of the trunk muscles involve both sides, total loss of trunk function does not seem likely to happen in case of stroke hemiplegia. According to core stability theory, ADIM as deep muscle movement coupled with the selective pelvic exercises providing the superficial muscle movement would more effectively be done as the trunk training. The selective pelvic exercises were done in our protocol because of having high feasibility for stroke patients in prior studies, positive effects regarding stroke rehabilitation included selective pelvic exercises. We designed a step-by-step core stability training program with selective pelvic exercises tailored for stroke rehabilitation. This was termed "core stability training" in the present study.

Trunk function disorders are generally documented in patients after stroke. Earlier reports have noted in them trunk muscle weakness, the delay of their activities, significant error in the position sense of the trunk5, center of pressure in which the person sits, a lower level of performance of the trunk movements,8 and asymmetry when they walk. Trunk function was associated with balance and walking ability in stroke patients and was also reported to offer a useful predictor of balance and walking ability as well as activities of daily living outcomes.

Several randomized controlled trials focused on trunk performance in the population of interest, and reports indicated that training enhanced trunk performance among experimental group participants. However, these studies either did not balance the amount of exercise offered by a control group or employed an overly wide range of trunk training interventions.(2)

One of the main goals of stroke rehabilitation is to help patients regain as much functional independence as possible. Mobility is an important part of functional independence because it allows patients to carry out their daily activities, perform self-care, and minimize their dependence on caregivers.

1.3 Core muscle stability

For stroke patients, there are no better basic tenets to achieve concerning the preservation of posture and balance with effective movement than to maintain core muscle stability. Core muscles encompass, in their group, several key structures including transverse abdominis, multifidus, diaphragm, and pelvic floor musculature. In most patients suffering from stroke, the core stability is disturbed. This prevents proper balance and posture and energy-efficient locomotion necessary for functional independence. Therefore, strengthening of the core muscles with rehabilitation exercises helps enhance trunk control by eliminating many compensatory movements, thereby the higher energy cost associated with walking. For appropriate rehabilitation interventions, therefore, the core muscle strength must be evaluated, and for this, the Sharman Core Stability Strength Test is being widely applied.

Compared with the control group, both groups of experiment improved significantly on all outcome measures from baseline to post training and from baseline to 12-mo follow-up ($P < 0.001$). There was no significant difference between the two experimental groups on all the measures ($P > 0.05$)(3)

It not only provides core muscle stability as part of trunk stabilization but also actively facilitates coordinated and symmetrical movement of the limbs in stroke patients. Movements in arms and legs are grossly inefficient and uncoordinated when the core musculature is not stable, greatly increasing the

risk of falling and movement-related injuries. This sometimes makes the stroke patient depend on compensatory strategies, such as overusing certain limb muscles or altering gait, leading to increased fatigue and potentially reducing the time a person can maintain engagement in activities like walking or standing. Building core stability may help to spread out the demands of movement more evenly throughout the body, reducing stress on limbs and joints. Therefore, strengthening the muscles in the core will ensure that the pelvis and spine are aligned during postures and movement and provide support for upright postures and balanced movement. It will, therefore, increase energy efficiency in movements. For instance, rehabilitation methods which involve exercises on those deeper stabilizers such as pelvic tilts, bridging, and dynamic stability are sure to lead to greater energy efficiency in movements without using much energy that usually characterizes stroke patients in most cases due to their muscular and neural fatigue

. This form of core stability exercises, especially when applied from a basis such as the Sharman Core Stability Strength Test, provides for individualization of interventions that promote more appropriate movement and support the attainment of better overall function, endurance, and quality of life during stroke rehabilitation.

General trunk muscle performance is improved with stabilization training in addition to muscle strength and muscular endurance training. The "core" and the concept of retraining "core stability" has been a burning issue of discussion lately in the low back pain and sports arenas. The "core muscles" include many muscles of the lumbo-pelvic-hip complex.(2)

Stroke is the most common cause of morbidity and long-term disability in Europe. It often imposes a considerable change on people's lives and is an economic burden to society. Stroke survivors often experience physical, cognitive, social, and emotional consequences after stroke. The healthcare offered after stroke aims to ease and support restoration of functioning and/or adaptation to disability, and to enable people with stroke to achieve optimal social integration. Therefore, rehabilitation is an important part of these services. However, stroke survivors

find themselves left with substantial activity and participation limitations and/or in need of daily help. They report long-term unmet needs for rehabilitation of up to 8 years after a stroke.(4)

To develop high-quality healthcare for stroke survivors it is essential to have a common understanding of the needs, experiences, and priorities of those living with the results of stroke. Reviews of self-reported problems experienced by stroke survivors and their careers place strong emphasis on the social aspects of re-establishing former identities and resuming previous occupational, family, social and recreational roles. Many stroke survivors and careers experience social isolation and worsening relationships with their spouses and family. In addition, emotional problems, typically long-standing depressions and anxiety are common. Even so, rehabilitation services seem to be aimed mostly at regaining function and, less, at enabling social participation and regaining former roles and responsibilities. A survey on the prevalence of unmet needs of community-dwelling stroke survivors across the United Kingdom 1–5 years after the stroke was conducted. The survey showed that nearly half of the survivors reported one or more unmet needs related to problems with mobility, pain, fatigue, memory, and concentration. Other studies have found that stroke survivors also report unmet needs related to activities of daily living (ADL). These needs are: social participation, mobility aids, home adaptation, housing, accessing financial support and benefits, information, rehabilitation and transport between 1 and 11 years after stroke(4)

The core is crucial for movement, ensuring balanced and efficient movement with the role it plays both in maintaining posture and in coordinating movement. These muscles are located in the transverse abdominis, multifidus, diaphragm, pelvic floor, and obliques, which, taken together, form a stabilizing network that allows controlled, complex movements by stabilizing the spine and pelvis. This stability is particularly important in stroke rehabilitation, where muscle weakness and neurological impairments can significantly limit trunk control and balance, increasing the risk of falls and limiting functional mobility. When core muscles are weak, the body compensates by overusing other muscle groups, which not only disrupts natural movement patterns but also raises the energy cost of actions such as walking or standing.

Core stability is generally used to strengthen the muscles around the abdominal, lumbar, and pelvic areas because the muscles of these areas are very important for stability as well as control of the lumbar posture through the use of tonic or postural muscles in whole-body exercises (Marshall and Murphy, 2005). The muscles that make up the core stability are multifidus, transversus abdominis, external/internal oblique abdominis, paraspinalis, gluteus, diaphragm in the rear part, and hip muscles. The ventral muscles like multifidus, transversus abdominis, and oblique abdominis provide core stability through cooperative contraction before movement out.(5)

Besides, the general problem of decline in function of core muscle, primarily the outer muscles, causes paralysis of the core muscle, decrease in contraction, and enhances the tendency of falling to the paralyzed side, hence resulting in asymmetry. As CVA severely impairs balance and walking, which are basic requirements for any physical activity, loss in quality of life, affected patients undergo a huge loss (Handa et al., 2000). Thus, the physiotherapist must focus on dyspraxia and rehabilitation of balance and gait for patients who have suffered from brain damage so that such patients may lead an independent and functional life. Long since, the prognosis of CVA has been made on the basis of part and size of lesion. However, since the theory of brain plasticity was known, doctors know that the extent to which patients could recover can depend on the excellence of the rehabilitation program (Bach-y-Rita, 1981).(5)

Strengthening of core muscles through specific exercises improves sitting, standing, and walking with less effort and improved safety among stroke patients. Improved core stability enhances trunk control and allows for more symmetrical and coordinated movements of limbs important for daily activity and functional independence. It also reduces the load on peripheral muscles that usually bear more loads than they should when the core is not stabilized, thereby reducing the rate of fatigue and improving endurance. Rehabilitation programs emphasizing core stability exercises such as planks, bridges, and dynamic stabilization can radically improve a patient's balance, posture, and gait efficiency. This increased stability does more than just support physical recovery but also boosts confidence and psychological well-being. Therefore, patients can attain a higher level of engagement in their daily lives and greater autonomy.

1.4 Trunk control

Trunk control is an essential part of stability in posture and coordinated movement, which is highly important in stroke rehabilitation since it affects a person to stand, walk safely, and perform daily activities. Trunk is part of the spine and core muscle that works as the central axis of movements for the upper and lower limbs of the human body and whose activities include sitting, standing, walking, and reaching. Such posture and shifts in body balance can only be maintained, therefore, by good control of the trunk. Poor trunk control is the post-stroke condition for those patients as a result of muscle weakness, poor coordination between their neuromuscular coordination, and possibly asymmetrically activated core muscles that create postural instability and contribute to falls and other balance-related injuries and conditions. This instability limits the ability of patients to move independently, and what might seem like simple activities, such as transferring from a bed to a chair or reaching for objects, may be difficult or unsafe. Rehabilitation efforts that focus on trunk control are designed to strengthen the core muscles, enhance proprioceptive feedback, and improve balance responses in support of safer and more efficient movement patterns. Weight-shifting exercises and seated balance training are often used.

The rotation training of the trunk might permit better postural readjustment during movements as well as more coordinated limbs to carry out these ordinary everyday activities without energy or force. Improved trunk stability reduces compensatory strategies in the patient, such as relying on the upper limbs to provide support, thus making movements more natural and efficient. Regaining trunk control also gives patients greater confidence and independence, which leads to more participation in physical activity and social interaction and ultimately to a better quality of life.

In total, 1881 studies were screened, out of which 22 studies with 394 participants satisfied the inclusion criteria. The type of training included core stability exercises, trunk training that involved reaching or weight-shift activities, and proprioceptive neuromuscular facilitation. The dose of therapy was reported to vary from 3-36 hours between the studies. The median of PEDro

score was at 6/10 with low risk bias. Meta-analysis was done using a random-effects model because of heterogeneity in study population, interventions received, and follow-up length. The overall treatment effect was huge for trunk control standardized mean differences (SMD) 1.08 (95% CI: 0.96–1.31), standing balance SMD 0.84 (95% CI: 0.04–0.98) and mobility SMD 0.88 (95% CI: 0.67–1.09).(6)

Trunk instability is one of the major problems in survivors following stroke. We investigated the effects of weight-shift training (WST) on an unstable surface in sitting position on trunk control, proprioception, and balance in individuals with chronic hemiparetic stroke.(7)

We found that significantly increased mean TIS scores were seen from baseline to 3 months post-treatment (7.74); the increased scores were maintained at 6- and 12-month follow-ups (8.60 and 8.43, respectively). Secondary outcomes in the experimental group showed significant and clinically meaningful results in all of them. Between groups, fall risk was significantly reduced at 6 and 12 months.(8)

Basic trunk control is necessary for posture stabilization and coordinated limb movements; its impairment, which often occurs after a stroke, may be detrimental to the function of the patient and increase his dependency. Impaired trunk control often presents with challenges in maintaining an upright posture, reduced balance, and restricted capacity to initiate and control movements of the trunk to fulfill everyday activities. An imbalance posture occurs due to the deficiency or reduced activation of trunk muscles. Most of the patients tend to shift to one side. Their center of gravity will get disturbed and increase the possibilities of falls. Such instability does not only affect their simple movement like sitting, lying, or standing but even the more complex movement as turning, reaching, and transferring from one surface to another. In stroke patients, poor trunk control results in bad gait mechanics because the trunk does not stabilize the body to use compensatory movements, which in turn decrease symmetry and efficiency of gait, often causing fatigue and energy expenditure. Rehabilitative strategies for trunk control impairment include returning symmetrical muscle activation, improving proprioceptive awareness, and enhancing the stability of

the core in order to allow for more fluid, controlled movements. It may retune the trunk musculature through exercises that involve supported and unsupported seated balance tasks, core strengthening routines, or dynamic stability exercises. These would all improve the patient's balance and stability in exchange for enhancing greater trunk control, which will help movement become more confident and utilize energy more efficiently toward final progressions to functional independence and better quality of life.

1.5 Energy cost of walking

The energy cost of walking is an important measure in evaluating functional mobility and endurance, especially in populations with movement impairments, such as stroke patients. This term describes the amount of energy needed to walk at a certain pace, which is usually increased in individuals with gait abnormalities or postural instability due to inefficient movement patterns. Walking after strokes is characterized, for those survivors, often by more compensatory patterns of performance, including but not restricted to asymmetrical steps; altered trunk movement; upper body involvement is also above the norm—and results in raised energy costs for walking and thus reduced endurance and tolerance to distance of walking because of early exhaustion. Thereby, all this will indirectly restrict independence as well as participation in activity. In clinical and rehabilitative contexts, the energy cost of walking is highly relevant for professionals, especially in assessing the economy of gait and the type of obstacles a patient face when walking, thereby making it easier for them to develop focused interventions that will improve walking economy.

The patients spent significantly more energy on their walks than the controls. The exercise portrayed in guidelines may be a moderate intensity for stroke individuals: stroke-specific exercise guidelines are required.(9)

No significant differences were noted for the PCI or V̇o2 between test and retest. For both PCI and V̇o2 per distance, the stroke subjects demonstrated higher values than the healthy subjects. PCI presented with a greater dispersion than V̇o2 when comparing test and retest. The regression analysis of PCI

indicated that the model including age, sex, group assignment, and V̇o2 could explain 53% of the variance. However, the PCI did not show this difference between walking with and without an orthosis, yet a statistically significant difference did occur in V̇o2.(10)

The most commonly used outcome measures to measure the energy cost of walking is the Physiological Cost Index (PCI). PCI has been shown to be both practical and reliable in calculating the energy expenditure associated with walking by computing the heart rate increase during walking compared to walking speed. Specifically, it is the difference between heart rate in the steady-state walking phase and resting heart rate divided by speed. This will then give an index in beats per minute per meter walked (beats/min/m) that reflects physiological effort a person exerts per unit distance. This makes PCI especially useful for ascertaining how a patient can walk efficiently in varying conditions. The fact that PCI is simple allows its implementation in clinical settings. For instance, it needs no equipment and is not invasive, making it the right choice for repeated measurement sessions while rehabilitation is ongoing.

High values for the PCI may reflect higher-than-normally required energy expenditure in walking by individuals who suffered a stroke, based on deficiencies in muscle strength, coordination, and balance in muscles affected by the stroke. Therefore, re-testing of measures of the PCI offers information that is objective regarding effectiveness of rehabilitation interventions in maximizing efficiency of walking, given that high values for the PCI indicate less-than-normally required energy, yet core stability and trunk control can be enhanced through practice, as well as an overall muscle activation pattern which can also be enhanced through exercise, and both of which contribute to lowering the value for the PCI. Moreover, PCI is helpful in defining personal therapeutic goals, for example, interventions centered on strengthening the core and trunk stability might be targeted to specifically reduce PCI values such that the metabolic cost of walking for a given patient would be reduced. In research, PCI is also widely used as a valid and reliable outcome measure in studies designed to compare the effectiveness of various rehabilitation protocols because it offers a measurable relationship between physiological effort and functional mobility. Therefore, this would mean that PCI not only assists in measuring the energy cost of walking but also becomes an indicator for outcomes regarding the

interventions put in place to restore the functional independence among stroke patients.

Ten patients with hemiplegia have been studied for the mechanical energy costs of walking. Two strides of the subjects' normal walking were subjected to a two-dimensional sagittal plane cinematographic analysis. The analysis provided continuous information about the mechanical energy costs of the whole body and each of its parts, the types of energy involved, and the amounts of energy conservation. The large head, arms, and trunk dominated the total pattern. Three major disturbances were found. For comparison, normal subjects who show energy-conserving negatively correlated potential and kinetic energy curves for the HAT, the subjects who presented the first disturbance had gross irregularity of the curves, with almost no possibility of exchange between energy types. In the second perturbation, curves of HAT showed some energy-saving parts, but levels of kinetic energy curves were very low, so there was little energy transfer. During the third perturbation, some transfer was apparent, but the pattern was again dominated by changes in potential energy in the form of a single large rise and fall, corresponding to swing phase of the affected limb. Each of these disturbances would need a separate treatment protocol. While mechanical energy analyses do not quantify some costs of energy, such as the work in holding up the body against the effects of gravity and that associated with contracting antagonist muscles, they could be quite helpful in identifying costly fluctuations in the patterns of energy during walking and in the prescription of appropriate treatment programs.(11)

1.6 Rationale

This study addressed the critical coupling between core muscle stability, trunk control, and energy metabolism in stroke patients. Enhanced core stability improves and enhances trunk control, a pre-requisite for more economical ambulation mechanics and less associated energy expenditure during walking. In light of this knowledge that the energy cost really matters for rehabilitation and is an important factor for regaining quality of life, this could inform focused therapeutic interventions aimed at the right areas. This can be possible by basing rehabilitation practice on a correlation that highlights the link between mobility independence and effectiveness in stroke recovery.

Comprehensive approach: in our study we are going to address this gap comprehensively by including stroke patient across all stages from acute to chronic. We are aiming to integrate sahrman core stability scale, trunk impairment scale (TIS) and energy cost of walking (PCI) as outcome measure a combination not found in current literature.

Existing gap: Our literature searches highlights a significant gap in research concerning the correlation between core stability, trunk control and energy cost of walking. This absence indicates a critical need for research in this area. Which type of trunk training is more useful to improve trunk performance in stroke

Clinical importance: Stroke survivors commonly face challenges with trunk control, balance, and walking abilities, leading to reduced mobility and increased energy expenditure. Understanding the role of core muscle stability in these aspects is crucial for developing effective rehabilitation strategies and improving patient outcomes.

This study concluded that core stabilization training is better as compared to the conventional physical therapy treatment for improving trunk impairments, functional ambulation, and quality of life among patients of stroke. Core stabilization training is also more effective in improving trunk mobility in sagittal plane. This study is registered in Iranian Registry of Clinical Trials IRCT20210614051578N1 and was approved by the local research ethics committee of Riphah International University.(12)

Due to reduced speed, more energy is spent in stroke during the gait cycle. Core muscle stability may improve this reaction time. Thus gait and balance are directly affected by core stability exercises(12)

Stroke Patient and the concept of the core stability is recent focus(**13**).

Chapter 02

Literature review

2.1 Introduction

Stroke motor impairments pose a severe challenge in rehabilitation, especially with regard to achieving functional mobility and independence. Muscle weakness, coordination impairment, and diminished postural control usually occur following a stroke, thereby impeding the gait efficiency of the patient. Rehabilitation aims to overcome these deficits by strengthening the muscles, stabilizing the individual, and increasing energy efficiency.

One of the factors affecting mobility in stroke patients is core muscle stability and trunk control. It is becoming increasingly apparent that these components are important for improving functional outcomes. Core stability is a term referring to the muscles of the abdomen, pelvis, and lower back that provide support for trunk alignment and posture. This is required for movement and balance. Trunk control is that aspect of a function so closely related to core stability; coordinated movements necessary for gait and everyday activities would be impacted. Neuromuscular inefficiencies commonly elevating energy cost would impact a patient's endurance and activity levels and thereby their quality of life directly, as endurance and activity levels are strongly influenced by any neuromuscular inefficiencies elevating energy cost in stroke patients.

The goal of this literature review is to synthesize the findings of the existing body of research into the roles that core muscle stability, trunk control play in determining the energy cost of walking for individuals who have suffered from stroke. This will be achieved through the review and discussion of physiological underpinnings, documented effects, and therapeutic interventions of these factors in order to highlight the current knowledge of the interplay of these relationships and contributions toward post-stroke mobility. The review also reveals some lacunas in literature, stating that there is a need for research of this type, like the present one, to discuss these variables together to develop a more lucid idea regarding how core stability interventions could reduce energy expenditure in stroke rehabilitation.

2.2 Overview of stroke and motor impairment

Stroke is among the most common causes of disability in the world. Millions of people worldwide experience a stroke every year, and it is caused by the sudden loss of blood flow to an area of the brain, resulting in lasting neurological damage and usually impairments in motor function. Depending upon the site of the lesion and the gravity of the stroke, there may be a varying loss of strength in muscles and coordination loss with poor equilibrium and limited functional mobility in patients. All these disorders of motion interfere with patient's capacity to carry on daily life activities and so severely limit independence and life quality of a patient.

Motor impairments result from disruptions in communicating between the brain and muscle, thus affecting posture control, balance, and moving the body. Effects include weakness on one side of the body, spasticity, and poor motor coordination. These deficits mainly affect patients' ability to stand and walk and affect their postures, thus hindering efforts to rehabilitate them further.

Compromised gait function is one of the most disabling aspects of post stroke motor impairment. Numerous patients suffering from stroke usually have abnormalities in gait, which includes asymmetrical steps, restricted range of movement at the affected joints, and weight transfer in inefficient and laborious walking pattern. Such changes not only decrease walking speeds but increase the cost of ambulation, hence it is difficult to maintain activity over time by the patient. As a result, patients who have suffered strokes are often vulnerable to developing secondary complications like reduced cardio fitness and muscle wasting, which arise from reduced physiologic activity.

The importance of core stability and trunk control has emerged recently in stroke rehabilitation, due to their role as foundational aspects in balance, coordination, and efficient movement. For developing effective interventions aimed at

improving walking efficiency and functional mobility, it is important to understand the nature of impairments in motor function post stroke and how these are related to core stability and trunk function.

Stroke or Cerebrovascular accident (CVA) is damage to the brain caused by an anomaly of blood supply to the brain. Stroke is now considered the third most fatal disease, and also an emerging cause of long-term disability in many developed nations globally. In the United States, about 15% of all strokes Hemorrhagic and 85% are ischemic. Strokes occur at any age but are much more common in the elderly, the death rate doubling every ten years between the ages of 55 and 85. While there are only a few sites in the country that actually measure stroke incidence, it is estimated that there are about 750,000 new strokes each year in the US. Stroke death Rates have been declining slowly since the 1950's but due to a slowdown in decline and graying of the population, the late 1990's saw an increase in the overall number of stroke deaths. World-wide, stroke, which has become the sixth leading cause of death, is projected to become the fourth most common cause of death in 2020. The mortality rates of stroke are unique distribution in the US. Stroke deaths are more common among males than females. Black Americans have the highest stroke death rate, Hispanics are intermediate and whites have the lowest rates. Deaths also vary geographically with blacks in North Carolina, for example, having twice the mortality rate of blacks in New York. However, because of the population makeup white women make up greater than 50% of all stroke deaths in the US. The most critical role of stroke lies in its impact on the individual. The brain is the most important organ in our body; its several functions enable us to interact with the environment and other people successfully. We depend on these interactions to lead a successful, independent day-to-day life. Thus, any disorder that affects the normal functioning of the brain will impair these interactions. The precise the nature of the impairment will depend upon the special specifics of the disorder.(14)

Most affected functions of the brain that result from a stroke is the normal motor function of the brain. Damage to any part of the brain that is concerned with motor control can be due to a motor impairment post a stroke. These areas range from cortical to subcortical regions of the brain. Some of the important regions of the brain involved in sensorimotor control are: The apparatus of the brain is: Primary motor cortex (M1), Premotor area, Parietal cortex, Cerebellum and Basal

Ganglia. All these regions contribute to the generation as well as the control of a voluntary movement.(14)

A major problem in correlating motor deficits with the location of the lesion is a significant variability between the locus of the lesion and the motor deficits. Despite substantial variability, some sensorimotor deficits can be traced to lesions to specific cortical areas. The different cortical areas where lesions can result in a motor deficit are shown in Fig 9. Most stroke lesions include several cortical areas rather which explains why in most cases there are distinct parts of these residual defects that decide the extent of residual motor function left intact. Both kinds of failures of nervous system lead to one form or another of inappropriate behaviors that can be generally categorized either as negative, meaning some particular ability normally maintained by system is now missing; or positive referring abnormal, stereotyped, responses that emerge later the system has been damaged(14)

2.3 Core muscle stability and stroke rehabilitation

The basic foundation of effective movement, balance, and postural control of a patient during stroke rehabilitation is the core muscle stability. Core stability is the coordination of abdominal, lower back, pelvic, and hip muscles for maintaining the trunk in a specific position and providing support during movements. Impaired core stability often leads to the inability to maintain posture, perform coordinated movements, or achieve stable gait among stroke patients. The core stability exercises enhance balance and reduce the risk of falls by enhancing functional mobility. It has been evident that the improvement in core strength, especially trunk strengthening along with controlled movement tasks enhances balance, reduces the risk of falls, and enhances the functional mobility of patients having a stroke. Patients are able to control their trunk movements better by strengthening the core muscles, especially useful for walking and other activities that are associated with balance and stability. Recent interventions have been based on core stability, and results show promise that core-focused exercises do significantly enhance motor control and functional independence, thereby potentially leading to a better quality of life for stroke survivors. Therefore, this paper's body of evidence supports the integration of

core muscle training as a key component of stroke rehabilitation programs aimed at optimizing recovery and improving mobility outcomes.

Current study hypothesized that Core stabilization training is better in improving trunk impairment, functional ambulation, quality of life and trunk mobility as compared to conventional therapy in post stroke patients. Postural control is considered an essential component for maintaining an upright posture during stroke rehabilitation. The set of core stability with standard physical therapy exercises of 5 days a week for 4 weeks has beneficial effects compared to standard physical therapy alone among hemiplegic stroke patients, despite of small sample size was studied. But significant effects in experimental group were reported increased muscle activity lower trunk with a P value < 0.05(12)

Trunk control is the ability of the trunk muscles to permit the body to maintain an upright posture and to execute weight shifts to maintain balance during static and dynamic postural tasks. Hemiplegia, a secondary result of stroke, is associated with severe unilateral muscle weakness and is associated with decreased mobility, balance, and activities of daily living (ADL), leading to loss of independence. After a stroke, impairments in trunk movement occur in hemiplegic patients in multidirectional fashion. Impairments are defined as weakness and delayed activation of trunk muscles, significant error in trunk position sense, inadequate control of the CoP, decreased trunk performance, and trunk kinematic asymmetry during gait. Even at the chronic phase of stroke, decreased activations of trunk flexors and extensors muscles and low peak torques have been reported in comparison to a healthy individual.(15)

Trunk function has always remained a high interest point of post-stroke rehabilitation and most modern trunk training programs contain exercises of core stabilizing, reaching, weight-shifting, or proprioceptive neuromuscular facilitation. All the approaches help in improving both static and dynamic balance of sitting posture, seated arm movements, and fall prevention. But all the rehabilitation programs discussed involved different postural tasks meaning that the degree of involvement of a therapist could range from variable limited involvement to less frequent replication, that in turn bring variability into the dosing of interventions given hence, heterogeneity within dosing and exercises

makes an intervention limit the treatment standardization and challenges results generalization based on their respective interpretation across the studies.(15)

The predictors of quality of life after stroke have been revealed to be age, sex, type of stroke, effected side, duration post stroke, severity of stroke, functional status, upper extremity and lower extremity motor function, balance, cognitive function, and depression. In the present study, it was evident that quality of life of the patients had improved substantially following treatment with core stabilization training when compared to conventional therapy (p-value < 0.05). These findings agree with previous research that irrespective of the type of exercise reported that physical rehabilitation significantly impacts improving the quality of life after stroke. Reports indicate that the performance of exercises shortly after the occurrence of a stroke at home reduce the degree of post-stroke disability and also improve the quality of life.(15)

2.4 Trunk control and functional mobility

Trunk control is also important in the achievement of functional mobility since it gives a stable core base to balance and posture and coordinated movement for daily activities of living and independent ambulation. A central role in stabilizing the body, trunk allows the efficient transfer of force from the upper to the lower extremities that supports such movements as reaching, walking, and transfer between sitting and standing. Post-stroke trunk control impairments are such a common condition that presents problems with balance, posture alignment, and gait, significantly affecting the patients' functional mobility. When there is weakness or incoordination of trunk musculature, as would be common in hemiplegic or hemi paretic patients, these individuals have reduced ability to balance and adjust posture upon dynamic movement, making apparently simple tasks laborious and less stable.

It is likely that improvements in trunk stability and strength will make a great difference in functional mobility among stroke survivors. These core stability exercises are strengthened through abdominal and back muscle strengthening.

Improvement of these aspects includes enhancement of balance, sitting stability, and walking efficiency. The numerous studies have proven that special exercises to strengthen trunk muscles do not only improve the balance of static and dynamic sitting but also improve the symmetrical gait pattern, reduce physical strain and energy cost while walking. This relationship between trunk control and mobility becomes particularly important in stroke rehabilitation where, most of the time, the objective is to restore a patient's independent ability to execute basic movements with as little assistance as possible.

The ability to maintain trunk stability during movement transitions influences functional mobility considerably, particularly in stroke rehabilitation. Rehabilitation programs with a focus on trunk rehabilitation by means of dynamic balance training, trunk rotation, and posture-correcting exercises are associated with greater autonomy in daily activities and reduced risk of falls. Therefore, it is also recommended to include trunk stabilization during rehabilitation of patients after stroke, since it directly correlates with improvement in the state of balance and walking and a more integrative type of recovery - stability, together with mobility.

There is substantial evidence to suggest that the inclusion of trunk training in the rehabilitation process improves ADL, trunk function, standing balance, walking ability, upper and lower limb functions, and quality of life in patients post stroke. Core-stability, selective-, and unstable-trunk training approaches were the most applied kinds of trunk training in most of the included trials. Results were mostly confirmed considering only the low risk bias trials, with very low to moderate certainty, according to the outcome.(16)

2.5 Energy cost of walking in stroke patient using physiological cost of index

PCI is a commonly used metric for the energy cost of walking in stroke patients by simply estimating how much energy or effort is spent through ambulation. The amount of oxygen consumed is proxies using heart rate, an index that is especially favorable for use in clinical applications because direct measures of oxygen uptake may not be obtained in such settings. This index is useful in stroke rehabilitation to measure gait efficiency and endurance; it can be tracked to follow improvements as patients undergo mobility training.

For stroke patients, the PCI is generally higher than for healthy controls because of greater muscular inefficiencies and poorer motor control, which translates into greater energy expenditure per unit distance walked. In the post-stroke patient, gait patterns may be altered in a compensatory fashion to include asymmetry or posture changes that increase energy to walk. As balance and trunk control improve, the PCI may decrease with a more efficient walking pattern and less effort.

The main goal of stroke patient rehabilitation is the restoration of ambulation, considering the latter's importance in increasing autonomy and social interaction. Given the fact that the rehabilitation period for stroke patients is quite long and costly, it is desirable to optimize the first phase during the in-patient stage. In these novel approaches to walking recovery, research on novel rehabilitation approaches, such as programs to relearn how to walk, has attempted to enhance functional outcomes and independence in the activities of daily living with a reduced recovery period. Task-oriented training and frequency, intensity and duration of exercise are the guiding principles of these novel approaches to walking recovery. Aerobic training, at least, has some benefits in the functional recovery of stroke populations: slows down the decline of physiological fitness reserves, improves walking capacity and enhances selected cognitive domains responsible for better sensory motor control. Other important benefits of aerobic training in stroke patients concern glucose tolerance and hyperinsulinemia and endogenous fibrinolysis, which can reduce secondary myocardial and cerebral atherothrombotic risk. As mentioned above, this multi-systemic treatment is aimed to promote the neurological as well as the cardio logical recovery outcomes.(17)

That oxygen cost may be proxies with PCI.
This parameter is related to the cost of oxygen and has similar values with the cost of oxygen in ambulatory patients after stroke.
It has failed to be useful even in discrimination between healthy controls.
and stroke patients. The PCI can be done relatively cheaply in a clinical setting as a routine procedure.(18)
This study tested the usefulness of an indirect index of oxygen cost, the Physiological Cost Index, and the ability of this index to discriminate between healthy adults and stroke survivors.(18)

2.6 Correlation between core stability, trunk control and energy expenditure

These also happen to be an emphasis point in rehabilitation, such that there is a strong tendency toward correlation between core stability and trunk control with high energy expenditure. Core stability relates to the ability in proper alignment and control in maintaining the trunk for correct movement and balance. As the core is stable enough to allow efficient transfer forces when walking or doing a different activity, this happens in minimizing unnecessary energy loss due to waste.

More importantly, the literature provides evidence showing that increased core stability increases trunk control, which further affects the energy cost of walking. Compensatory strategies often develop if the core muscles are weak or uncoordinated, with abnormal patterns of gait compensated for through an increase in the energy to move or walk. Such compensatory movements lead to an inefficient gait, characterized by asymmetries as well as additional muscle activations, and hence increase the overall energy expenditure.

For instance, patients suffering from stroke who have core stability are found to exhibit better gait mechanics and lower Physiological Cost Index (PCI) with low

heart rate responses while walking. Thus, it is concluded that improving the core stability is associated with enhancement of trunk control in the generation of more economical movement patterns with lower energy costs. An important result of specific training for core stability improvement is the improvement of trunk control. In everyday terms, walking at a lower cost of energy means a better endurance and more independent life for stroke patients.

This can be summarized as a relationship in which efficient core stability enhances trunk control, thus leading to more efficient movement patterns and less energy expenditure during walking. Therefore, rehabilitation programs focusing on core stability training can greatly improve functional mobility and quality of life in patients who have had a stroke.

2.7 Summary and identification of gap in existing literature

Stroke affecting 16 million people worldwide. In Pakistan the prevalence rate of stroke is 19%. Common leading impairment in stroke patient is the weakness of trunk muscle strength which consequently effecting ambulation**(19)**.there are around 12.2 million incident cases of stroke, 143 million disability adjusted life year(DALYs) lost. The incident and prevalence rate of stroke has been increased from (70%) and (85%) respectively in the past 30 years. Data on stroke prevalence are more readily available then those on incidence in east Asia. DALYs is the best measure of stroke burden. From hospitals based stroke registries, information are available on stroke sub type (table 4)**(20)**. For the increasing burden of stroke disease more effective strategies for the prevention and management are in need**(21)**. The data shows that 88% of the physician are aware of it least one of the 5 of the major symptom of stroke, only 46% are correctly identifying all of the five major symptoms**(22)** this study indicate a major gap in stroke patient management. Core stabilization is more effective than conventional physical therapy treatment for the treatment of trunk impairment, functional ambulation and quality of life of stroke patient**(19)**. Asia is contributing a largest portion to the global burden of stroke. There are large disparity in Asian country in health care providence which have considering impact on the control of the disease**(20)**.

The available literature on core muscle stability, trunk control, and energy expenditure in stroke patients was significant regarding interdependence among these factors that would influence the rehabilitation outcomes. These studies always showed that enhanced core stability is associated with improved trunk control, and the latter benefits the functional mobility and energy efficiency with ambulation. For instance, a study by Urrútia et al. (2021)(23). emphasizes the importance of core stability exercises in improving balance and mobility among subacute stroke patients, further indicating that focused interventions could result in better rehabilitation outcomes.(23)

The Physiological Cost Index was used as a reliable estimate in the measurement of the cost of energy expenditure attributed to walking, signifying an understanding about the link of the level of trunk control that occurs in stroke patients when performing the act of walking and the level of impairment or efficiency in the ability for a stroke survivor (Miller et al., 2020).(24)

This chapter gives a comprehensive review of existing research in relation to core muscle stability, trunk control, and energy cost of walking for patients who have had a stroke, with specific emphasis on the interrelations. Core muscle stability is identified as a critical factor that contributes to effective trunk control, which is an essential characteristic needed to maintain balance and execute functional movements. Indeed, many studies proved that core stability significantly improves walking efficiency and functional mobility after stroke and even saves energy when walking for some patients (Urrútia et al., 2021; Miller et al., 2020).

Literature shows that core stability in stroke patients relates to better postural alignment and motor control, reducing compensatory movements and the cost of walking. Such a relationship has been established in research through, for instance, Physiological Cost Index (PCI) links between improvements in trunk control and reduced energy expenditure, hence emphasizing the necessity for specific rehabilitation approaches, incorporating training in core stability.

Though several gaps in literature have been identified, this chapter provides several gaps that are necessary to be filled. It has been observed that core stability can influence energy expenditure through mechanisms, which is underexplored. Interventions have mainly led to general outcomes without any specific consideration of mechanisms behind the physiological processes. An area of future research is the lack of standardized assessment protocols that combine evaluations of core stability and trunk control with direct measures of energy expenditure.

This chapter therefore stresses the need for personalized rehabilitation strategies, since individual responses to core stability training may vary widely in patients with stroke. More robust comparative studies of various training modalities are thus necessary to determine the best ways to enhance core stability while reducing energy expenditure during walking.

Conclusion While much of the literature reports the existence of a positive relation between core stability and energy expenditure, as well as trunk control, research that is more comprehensive needs to be conducted to help establish the best rehabilitation strategies toward improved outcomes for survivors with stroke.

Chapter 03

Methodology

3.1 Material and methods:

3.1.1 Study Design

Analytical cross-sectional study

3.1.2 Study Settings

Hayatabad medical complex (HMC), Rehman medical complex (RMI), institute of physical medicine and rehabilitation (IPMR).

3.1.3 Study Duration

06 months.

3.1.4 Sample Size

(with justification of its calculations and reference used).

$n=Z^2 \times P \times (1- P) \div E^2$

Where:

n is the sample size.

Z is the Z-value (the number of

standard deviations from the mean), which is 1.96 for a 95% confidence level.

F is the estimated prevalence of the condition (5% or 0.05 in this case).

E is the margin of error, often set at 0.05 for 5%.

Let's plug in the values:

$n= (1.96)^2 \times 0.05 \times (1 - 0.05) \div (0.05)^2$

$n = (1.96)2 \times 0.05 \times 0.95 \div (0.05)2$

$n = 3.8416 \times 0.05 \times 0.95 \div 0.0025$

$n = 0.182182 \div 0.0025$

$n \approx 72.87$

Therefore, the required sample size is approximately 73 participants. (12)

3.1.5 sample technique

Non probability convenient sampling technique.

3.2 Sample selection

3.2.1 Inclusion Criteria

we are including only those patients having full consciousness without suffering from any sever psychiatric condition or taking any sedative medication which can vary outcome measure. The level of consciousness is defined as being awake without external stimuli. **(25)**. We are including those participants which have conformity evidence of stroke. By observing patient magnetic resonance imaging and computed tomography**(25)**. We are including participant from all ages and gender suffering from any type of stroke, the patient may be in acute, subacute or in chronic stage of stroke. We are including only those patients have access to Hayatabad medical complex (HMC), Rehman medical institute (RMI)and Institute of physical medicine and rehabilitation (IPMR)clinic. Trunk impairment scale would be used for accessing patient would be used for grading patient stability of core muscle **(26)**. Physiological cost index would be used for accessing energy cost of walking.**(27-29)**.patient scoring more than 24 to 30 on mini mental state examination (MMSE) are included which indicate normal cognition**(30)**trunk control impairment(TIS)**(31)**. Sahrman core stability test

3.2.2 Exclusion Criteria

subjects having past medical history of sedative medication or suffering from severe medication as these patient are not appropriate for our outcome measures

(TIS)**(25)**. We are excluding those patient who have undergone recent surgery or having exacerbation of stroke **(25)**. Participant with obvious bone deformity are excluded**(31)**. Subjects with uncontrolled hypertension, suffering from severe cardiac condition or having peripheral vascular disease and any chronic obstructive pulmonary disease as asthma are excluded as they may contradict physiological outcome measure accessed during study**(32)**. We are excluding all those patients who are outside our selected demographic location. Patient scoring less than 24 to 30 on mini mental state examination (MMSE) are excluded which indicate abnormal cognition**(30)**.female patient with current pregnancy, acute low back pain, acute limb injury or any musculoskeletal condition affecting response to exercise (sahrman core stability test may be compromised)**(33)**.

3.3 Data collection procedure

Detailed inclusion of subjects and data collection plan, including briefs about laboratory procedures, surgeries etc. Must clearly explain how the researcher will flow his data collection plan right from start till finishing the follow up on subjects or material).

Aim of the research: We are aiming in this research to explore the correlation among core muscle stability by using sahrman core stability test with trunk control impairment by using trunk impairment scale (TIS) and energy used during walking by using physiological cost index in stroke patient.

Type of data:

Quantitative data would be collected throughout the research by using our afore mentioned outcome measure.

Overt observation would be used (the patient is aware), we would collect data after observing the patient (indirect observation).

3.3.1 Method and procedure for data collection

After approval from institute board review board (IRB). We are collecting data from patient using non probability convenient sampling technique, patient would

be accessed for any exclusion criteria, then they Will be recruited according to our inclusion criteria. First, we would be grading patient core stability by sahrman core stability test which have five level of grading system moving from easier to harder if the patient is unable to perform at a particular level the stability of core muscle would be graded according to the level without exceeding our measure level of stability. Then we are going to access patient trunk control and energy use during ambulation or walking for five minutes. For trunk control impairment we are using trunk impairment scale

3.3.2 sharman core stability strength test

Sahrmann Core Stability Test Level 0 Unable to achieve level 1 position Level 1 Begin in supine, hook-lying position while abdominal hollowing. Slowly raise 1 leg to 100 deg of hip flexion with comfortable knee flexion. Bring opposite leg to same position. Level 2 From hip flexed position, slowly lower 1 leg until heel contacts surface. Slide heel out to fully extend the knee. Return to starting flexed position. Level 3 From hip flexed position, slowly lower 1 leg until heel is 12 cm above surface. Slide heel out to fully extend the knee. Return to starting flexed position. Level 4 From hip flexed position, slowly lower both legs until heel contacts surface. Slide heel out to fully extend knees. Return to starting flexed position. Level 5 From hip flexed position, slowly lower both legs until heels are 12 cm above surface. Slide heel out to fully extend knees. Return to starting flexed position.

3.3.3 Trunk impairment scale (TIS)

3.3.3.1 static sitting balance score /7

1)patient can keep starting position for 10s. 2) therapist crosses strongest leg over weakest leg, keep position for 10s. 3) patient crosses strongest leg over weakest leg.

3.3.3.2 Dynamic setting balance: score /10

1)touch seat with right elbow, return to starting position (task achieved or not). 2) repeat item 1 (evaluate trunk moment). 2) repeat item 1(compensation strategies used or not). 4) touch seat with left elbow, return to starting position (task achieved or not). 5)repeat item 4(evaluate trunk moment). 6) repeat item 4(compensation strategies used or not). 7) left right side of pelvis from seat, return to starting position (evaluate trunk moment). 8) repeat item 7 (compensation strategies used or not). 9) lift left side of pelvis from seat, return to starting position (evaluate trunk moment). 10) repeat item 9 (compensation strategies used or not)

3.3.3.3 Coordination: score /6

1)rotate shoulder girdle 6 times (move each shoulder 3 times forward). 2) repeat item 1, perform with in 6s. 3) rotate pelvis girdle 6 times (move each knee forward). 4) repeat 3, perform within 6s

TRUNK IMPAIRMENT SCALE

Starting position for all items: sitting, thighs horizontal and feet flat on support, knees 90° flexed, no back support, hands and forearms resting on the thighs. The subject gets 3 attempts for each item. The best performance is scored. The observer may give feedback between the tests. Instructions can be verbal and nonverbal (demonstration).

Item	Task Description	Score Description	Score	Remarks
	Static Sitting Balance			
1.	Keep starting position for 10 s	Falls or needs arm support Maintains position for 10 s	0 2	If 0, total TIS score is 0
2.	Therapist crosses strongest leg over weakest leg, keep position for 10 s	Falls or needs arm support Maintains position for 10 s	0 2	
3.	Patient crosses strongest leg over weakest leg	Falls Needs arm support Displaces trunk >10 cm or assists with arm Moves without trunk or arm compensation	0 1 2 3	
			/7	
	Dynamic Sitting Balance			
1.	Touch seat with right elbow, return to starting position (task achieved or not)	Does not reach seat, falls, or uses arm Touches seat without help	0 1	If 0, items 2+3 are also 0
2.	Repeat item 1 (evaluate trunk movement)	No appropriate trunk movement Appropriate trunk movement (shortening right side, lengthening left side)	0 1	If 0, item 3 is also 0
3.	Repeat item 1 (compensation strategies used or not)	Compensation used (arm, hip, knee, foot) No compensation strategy used	0 1	
4.	Touch seat with left elbow, return to starting position (task achieved or not)	Does not reach seat, falls, or uses arm Touches seat without help	0 1	If 0, items 5+6 are also 0
5.	Repeat item 4 (evaluate trunk movement)	No appropriate trunk movement Appropriate trunk movement (shortening left side, lengthening right side)	0 1	If 0, item 6 is also 0
6.	Repeat item 4 (compensation strategies used or not)	Compensation used (arm, hip, knee, foot) No compensatory strategy used	0 1	
7.	Lift right side of pelvis from seat, return to starting position (evaluate trunk movement)	No appropriate trunk movement Appropriate trunk movement (shortening right side, lengthening left side)	0 1	If 0, item 8 is also 0
8.	Repeat item 7 (compensation strategies used or not)	Compensation used (arm, hip, knee, foot) No compensation strategy used	0 1	
9.	Lift left side of pelvis from seat, return to starting position (evaluate trunk movement)	No appropriate trunk movement Appropriate trunk movement (shortening left side, lengthening right side)	0 1	If 0, item 10 is also 0
10.	Repeat item 9 (compensation strategies used or not)	Compensation used (arm, hip, knee, foot) No compensation strategy used	0 1	
			/10	
	Coordination			
1.	Rotate shoulder girdle 6 times (move each shoulder 3 times forward)	Does not move right side 3 times Asymmetric rotation Symmetric rotation	0 1 2	If 0, item 2 of also 0
2.	Repeat item 1, perform within 6 s	Asymmetric rotation Symmetric rotation	0 1	
3.	Rotate pelvis girdle 6 times (move each knee 3 times forward)	Does not move right side 3 times Asymmetric rotation Symmetric rotation	0 1 2	If 0, item 4 is also 0
4.	Repeat item 3, perform within 6 s	Asymmetric rotation Symmetric rotation	0 1	
			/6	
		Total Trunk Impairment Scale	/23	

3.3.4 Physiological coast index (PCI)

Then the patient will be instructed to calm and relax, so that the heart rate come to steady state then the patient heart rate be measured for the second time this tie in resting or sitting it may be lying if the patient feels tired that data would be recorded.

For knowing how much energy the patient is expending during walking we are going to use physiological cost index (PCI) we would access patient heart rate.

First patient would be instructed to set for a couple of minutes to calm the patient. Then the patient would walk for five minutes while heart rate monitor is attached to patient waist or wrist using digital heart rate monitor band, the recording would be noted.

While the patient is walking, we are going to measure patient speed of walking via how much distance in(m) the patient is going to cover in five minutes (m/min).

Then the difference would be calculated (HR during walking - steady state HR).

PCI =HR during walking – steady state HR)/walking speed (m/min)

At last we would be comparing patient core muscle stability score with trunk impairment control and energy cost of walking.

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Useful Equations: $\boldsymbol{PCI = Working\ HR - Rest\ HR / Walking\ Speed\ Walking\ Speed = d/t}$

Variables and constants:

PCI is the Physiological Cost Index

HR is heart rate

d is the distance traveled

t is elapsed time.

3.4 Data analysis procedure

We would analyze our data using spss version 23

Standard deviation, mean would be used for descriptive statistic. spearman rank correlation

Will be used for association between core muscle stability and trunk impairment. To know the interlink between trunk control impairment and energy cost of walking Pearson correlation will be taken into consideration.

Chapter 04

key finding and interpretation

4.0 Participation characteristic and base lie characteristic.

4.0.1 Demographic information:

4.0.1.0 Age and gender distribution

The study sample consisted of 73 participants aged between 20 to 80 years with a mean age of 59.5% year Among these participants, 46.8% were male and 35.2% female. Most of the participants were in the chronic phase of stroke recovery with53.1% suffering from left-side hemiplegia and 46.9% from right-side hemiplegia. Additionally, 33.8% of participants reported comorbidities such as hypertension or diabetes that are common among patients with stroke and can influence the outcome of rehabilitation. The diversity of this sample allows for a complete analysis of the relationship between core stability, trunk control, and the energy cost of walking.

Demographic characteristic	N (%)	Notes
Total Participants	73	
Age range	20 - 80 years	
Mean Age	59.5 years	
Gender		
Male	34 (46.8%)	
Female	26 (35.2%)	
Stroke Phase		
Chronic Phase	49.32%.	Most of the participants were in chronic recovery
Hemiplegia Type		
Left-Side Hemiplegia	39 (53.1%)	
Right-Side Hemiplegia	34 (46.9%)	
Comorbidities		
Hypertension/Diabetes	25 (33.8%)	Common among stroke patients

Table 1 Age and gender distribution

Interpretation of Demographic Characteristics of Study Participants:
Total Participants: A diverse representation in terms of age, gender, and clinical conditions pertinent to stroke recovery exists in the sample of 73 individuals.
Age Range and Mean Age: The age ranges of participants are between 20 years and 80 years, with a mean age of 59.5 years. The average age means that most people involved fall within the group of older adults, generally the group of people who usually experience a stroke and thereby need rehabilitation after a stroke.
Gender Distribution: The sample comprised 34 males (46.8%) and 26 females (35.2%). The small gender difference in the population could be interpreted as having a gender-related prevalence in the sample or simply as a reflection of the general population trends amongst stroke patients.
Stroke Stage: Fifty percent of the respondents were in the chronic stage of stroke recovery, thus most of them had experienced their strokes for long enough to have reached a stage where they maintain their ongoing needs of recovery. A focus on the chronic stage is relevant to long-term rehabilitation

strategies or activities such as those concerned with developing or enhancing core stability.

Left-sided hemiplegia occurred in 39 (53.1%) of participants, while right-sided hemiplegia occurred in 34 (46.9%) of participants.
This nearly equal split can be taken to support generalisability to both left- and right-sided impairments.

Comorbidities: In this group, 25 (33.8%) patients were found to have comorbid conditions of hypertension and
diabetes. Literature would also support this fact that the prevalence of such com orbid conditions in a patient who has suffered from stroke is very high since these are risk factors that might lead to the cause
of stroke. These will once again emphasize the necessity for an integrated appro ach towards rehabilitation in considering comorbid health problems that may impede recovery and functional outcome.

4.0.1.1 Ethnicity and Socioeconomic Background

Characteristic	N (%)	Description
Ethnicity		
Muslim	73 (100%)	All participants identified as Muslim.
Occupational Status		
Labor	45 (61.6%)	Engaged in manual labor.
Professional	10 (13.7%)	Employed in professional occupations (e.g., teachers, doctors).
Housewife	15 (20.5%)	Responsible for household duties.
Sedentary Lifestyle	3 (4.1%)	Not engaged in regular physical activity.

Table 2 Ethnicity and socioeconomic background.

Ethnicity: All the respondents are Muslim (100 per cent), making the sample ethnically and religiously homogeneous.
This may represent the dominant population in the region where the study was conducted, providing cultural uniformity across the sample.

Occupational Status:

Labour, 45 participants or 61.6% of total had been involved in manual occupations. The most likely ones to do such may perhaps have much demands physically within their lives everyday tha t could be transformed to recovery processes and, thus, rehabilitation exercises most probably they would require.
Professional: The smallest group was professional, who, at 10 (13.7%), were teaching or healthcare occupations. This group may have different levels of physical activity than manual laborers and different functional demands.
Housewife: About 20.5% (15 participants) were involved in household activities, which might be related to moderate physical activity. The functional goals in rehabilitation for this group may be to improve mobility and independence in daily activities.
Sedentary Lifestyle. Only a few (3, or 4.1%) reported a lifestyle that was characterized by limited participation in regular physical activities.
This smaller subgroup possibly has specific rehabilitation needs for possibly lower baseline physical fitness levels that could influence rehabilitation outcomes.

4.0.2 Stroke-related Information

Duration Range	No of chronic cases (N)	onset
1 year	6	chronic
2 years	5	chronic
3 years	4	chronic

4 years	8	chronic
5 years	8	chronic
6 years	3	chronic
7 years	1	chronic
8 years	1	chronic

Table 3 chronic stroke cases

Duration range	**No of acute and subacute (N)**	**onset**
2 days	1	acute
3 days	5	acute
5 days	2	acute
10 days	2	acute
20 days	1	acute
29 days	1	acute
1 month	3	acute
2 months	8	subacute
2.5 months	1	subacute
3 months	13	subacute

Table 4 acute and subacute stroke

4.1 Findings on Core Muscle Stability, Trunk Control, and Energy Cost of Walking

4.1.0 core muscle stability

4.1.0.0 score and distribution

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
SCS	73	5.00	1.00	6.00	3.9726	.15106	1.666
Valid N (listwise)	73						

Table 5 core muscle stability statistic

The statistical findings for the SCS probably measuring a core stability measure, for a sample of 73 participants, are discussed in relation to the distribution and central tendency of scores for core stability. The results are as follows:

Range : The scores of core stability range from a minimum value of 1 to a maximum value of 6.
This has a range of 5 units. That is, the scores for the subjects spread over a wid e range.

Mean (3.97). The mean score of the mean score is estimated to be about 3.97 points assuming the use of the 1 through 6 scale. Since most of the respondents scored near a midpoint along this scale, it would be inferred on average that participants have moderate scores for their core stability level as some are rated closer to the extremes in either end.

Standard Error (0.151): The moderately small standard error shows the sample mean, 3.97, as a highly likely value for the population mean if the experiment is carried out since other

replicates average scores are also most probably in the same order of magnitude.

Variance
(1.666): Variance which represents intermediate dispersals on either side of mea n scores, while variation was relatively less extreme with diversity within the cores' stability of the sample set.

4.1.0.1 core muscle stability bar chart

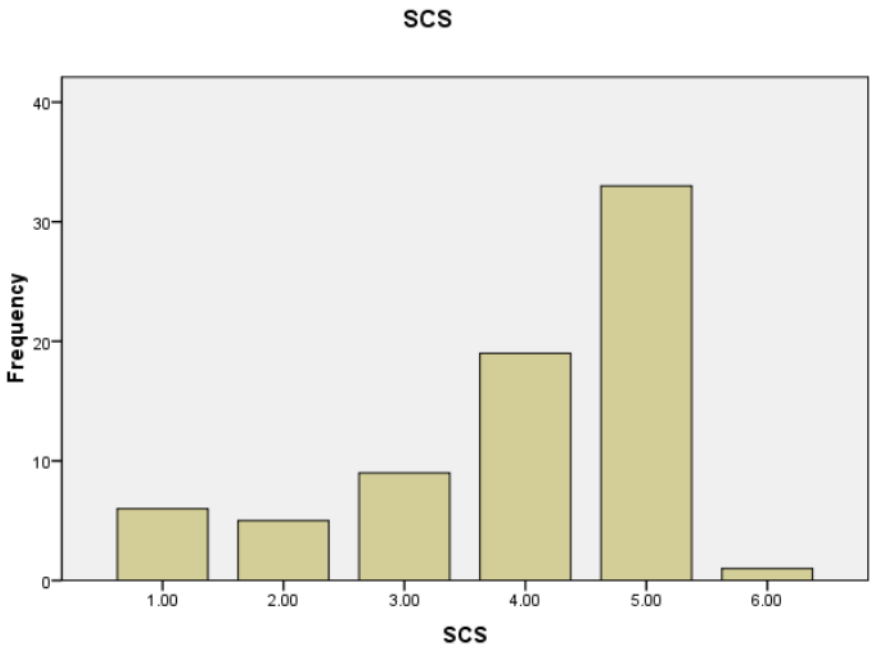

Figure 1 Sharman core muscle stability test bar chart

4.1.1 Trunk control score

Descriptive Statistics								
	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
SSB	73	5.00	2.00	7.00	6.4247	.10307	.88062	.775
DSB	73	10.00	.00	10.00	3.8630	.25232	2.15584	4.648
COORDINATION	73	6.00	.00	6.00	2.8493	.14022	1.19805	1.435
TIS	73	14.00	7.00	21.00	13.1096	.36209	3.09373	9.571
Valid N (listwise)	73							

Table 6 Trunk control score

SSB, (Static Sitting Balance):
Range=5; MIN=2; MAX =7;
Mean= 6.42-
nearly at top end, with the average being within those who could sit that many s econds balanced without assistance of hands.
Standard Deviation (0.88) and Variance (0.775): This is a low range of variation around the mean, suggesting that
most the participants obtained scores in SSB at similar ranges.

DSB (dynamic sitting balance):
Range: 10, score range: 0 to 10.
Mean = 3.86 indicating that the performance was lower on average as compared to SSB.
Standard Deviation (2.16) and Variance (4.648): There is
high variability, as the participants scored widely, from very high to very low.

COORDINATION:
Range: 6, with scores ranged between 0 and 6.
Mean: 2.85, falls in the lower half of

the range, indicating the average coordination is moderate.
Standard Deviation (1.20), Variance (1.435): Moderate spread out from the mean, denoting coordination ability for participants is quite spread around.

TIS: Trunk Impairment Scale
Range: 14, with scores of 7 to 21.
Mean: 13.11, which has a score close to middle, indicating an average capacity for trunk control in these participants.
Standard Deviation (3.09) and Variance (9.571): It showed a greater variation; that is, subjects were excellently spread out regarding trunk control and the fact that there were various scores between the lower extreme and the higher extreme.
Summary Interpretation: In general, participants performed better in SSB, with lower mean scores and greater variability in DSB, Coordination, and TIS. The range and standard deviations suggest that some of the variables, such as DSB and TIS, have a wide spread of performance levels, suggesting participants differ significantly in their ability across these particular measures. Such variation may point to the extent of individual differences in the physical or motor function abilities within the sample.

4.1.1.0 Bar chart

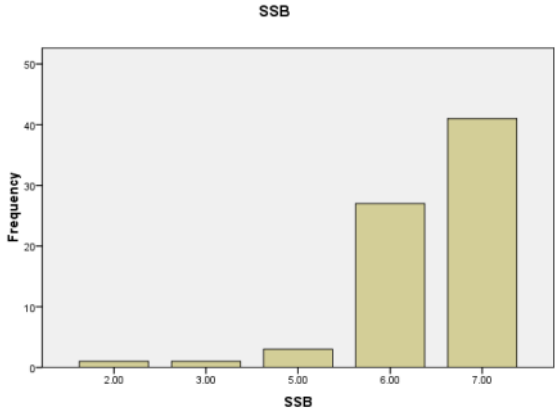

Figure 2 Static sitting balance bar chart

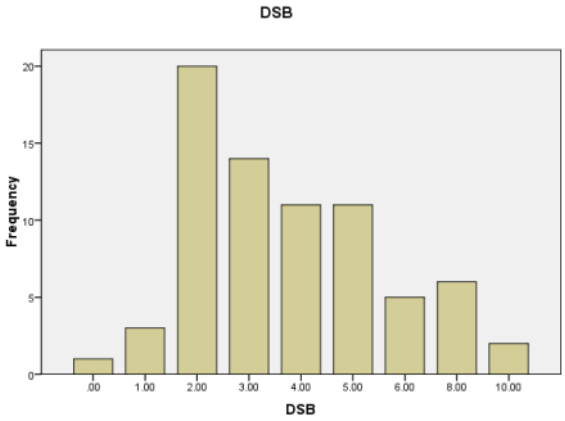

Figure 3 Dynamic sitting balance bar chart

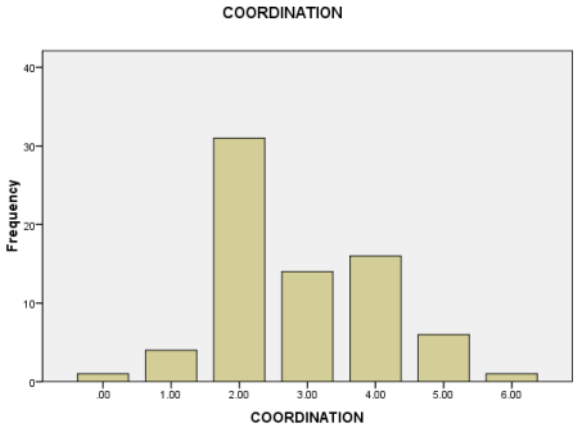

Figure 4 Coordination bar chart

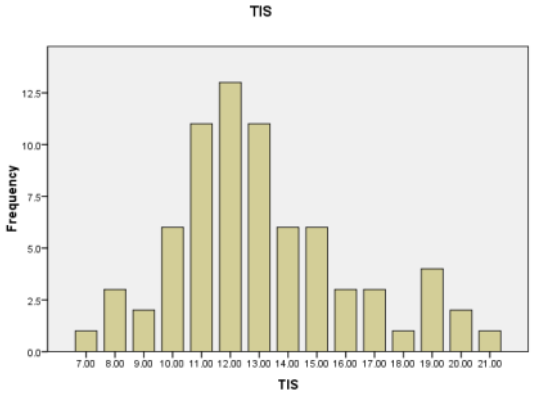

Figure 5 Trunk impairment scale

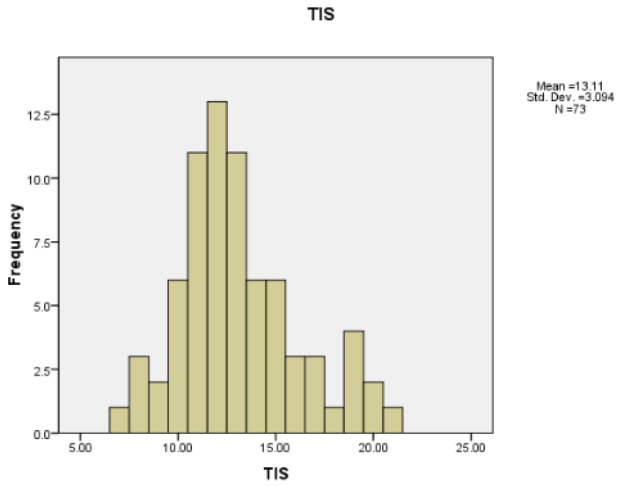

Figure 6 Histogram of trunk impairment scale

4.1.2 Energy cost of walking

Statistics		
PCI		
N	Valid	75
	missing	0
Mean		.7989
Median		.6600
Mode		.34
Std. Deviation		.52674
Variance		.277
Range		2.09
Sum		58.32

Table 7 Physiological cost index statistic

The PCI is the physiological effort or energy cost incurred in walking, usually established based on changes in heart rate due to alterations in walking speed. Interpretation of Statistical Outcomes for PCI of 75 Participants
It means the mean PCI value of participants is 0.7989, indicating a moderate energy cost of walking. Lower values of PCI usually indicate effective walking, while higher values of PCI indicate a high cost of walking.

Median (0.6600) and Mode (0.34): The fact that the median is lower than the mean's value indicates that although the majority of the people possess relatively low to average PCI values, some may possess much larger values and hence are skewed upward in the mean.

Standard Deviation (0.5267) and Variance (0.277): These values show a moderate spread of PCI scores around the mean, indicating that participants have different energy costs of walking, though not drastically.

Range (2.09): The PCI values range between 2.09 units, showing that there was a significant difference between the lowest and highest

scores, hence different levels of walking efficiency among participants.

Sum (58.32): It refers to the total PCI score of all participants,
which may be necessary to understand a general physiological cost within this group.

Summary Interpretation The majority of the sample of participants have a moderate or low PCI, which might reflect that most people would be using energy efficiently for walking. However, those with higher scores raise the overall mean, indicating a physiological cost of walking
of higher values for some subjects. This distribution
could perhaps be attributed to differences in participants' physical fitness, motor control, or recovery stage.

4.1.2.0 Bar chat of physiological cost of index

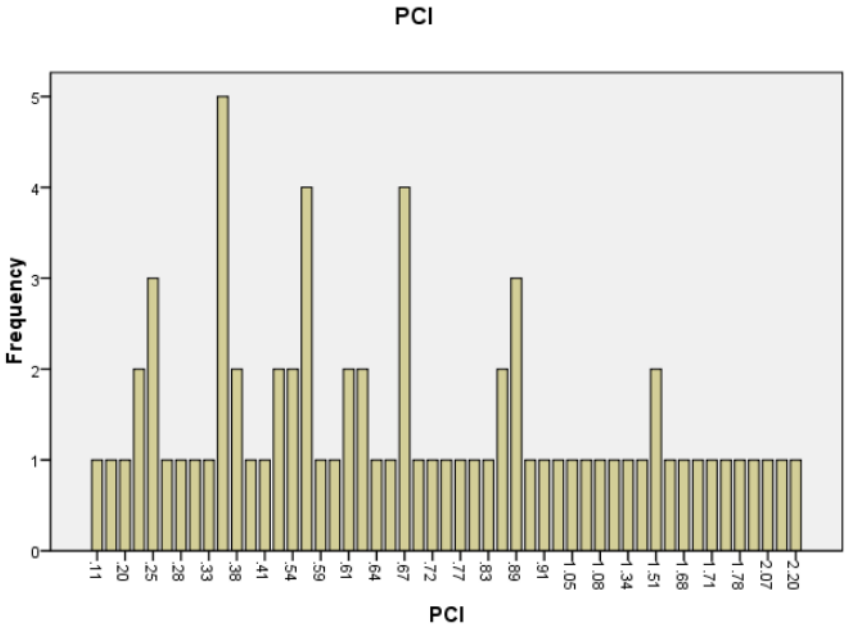

Figure 7 Bar chart of physiological cost of index

4.2 Statistical Analysis and Correlation Findings

4.2.1 Descriptive statistic

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
SCS	73	5.00	1.00	6.00	3.9726	.15106	1.666
TIS	73	14.00	7.00	21.00	13.1096	.36209	9.571
PCI	73	2.09	.11	2.20	.7989	.06165	.277
Valid N (listwise)	73						

Table 8 Descriptive statistic of sahrman core stability strength, trunk impairment , and energy cost of walking.

SCS: Sharman Core Stability Strength Test
Range: 5 scores ranging from 1 to 6.
Mean : 3.97 is the average; that means participants have, on an average, a moderate level of core stability score almost at the center of the scale.
Variance : 1.666; medium variance, therefore, considerable variation in strength with various levels of stability among the participants.
Explanation: Average
SCS rating means the participants are moderately strong for core stability as a group, although it varied at times when they scored less and someti mes scored more.

TIS (Trunk Impairment Scale):
Scale 14 scale from 7 to 21
Mean is 13.11, close to the middle of the scale, representing moderate impairment in the trunk control area, therefore, participants scored almost at the center of the scale.
Variance (9.571): Higher variance implies that the spread is greater in trunk impairment. Significant differences are found among the participants concerning trunk control.
Interpretation: Levels of trunk function could be implied from TIS scores, and th erefore, some participants have a better level of trunk control whereas others

may be challenged at the level of stability and
coordination. It might affect the whole balance and mobility level in those participants.

PCI Physiological Cost Index:
2.09 with 0.11 to 2.20 values.
Mean (0.7989): Average PCI describes moderate energy cost in walking.
Variance (0.277): Small variance shows that mean PCI values of most of the subjects lie close to
the group mean, hence showing minimum physiological cost variability among t he subjects during walking.

Conclusion: On average,
a moderate mean PCI shows that generally, the subjects incur a reasonable walking energy
cost with minimum physiologic cost variability among them.
Summary: The subjects seem to have core stability and trunk control at moderate levels, though they have wide ranges in scores for trunk function (TIS). This would indicate that individuals vary regarding their motor control. PCI scores indicate moderate energy cost for walking with low variability; this suggests that the efficiency of walking is similar
for the subjects. It therefore seems that the variation of physical ability, particularly regarding trunk stability and strength, might affect mobility and rehabilitation outcome.

4.2.2 Correlation Between Core Muscle Stability Trunk Control and energy cost of walking

Correlations				
Control Variables			TIS	PCI
SCS	TIS	Correlation	1.000	-.370
		Significance (2-tailed)	.	.001
		df	0	70
	PCI	Correlation	-.370	1.000
		Significance (2-tailed)	.001	.
		df	70	0

Table 9 partial correlation analysis of sahrman core stability strength with trunk control impairment and energy cost of walking

Meaning of Correlation Findings
Correlation Coefficients:

TIS, or Trunk Impairment Scale: The SCS-core muscle stability-
TIS correlation coefficient was found to be -0.370, meaning it represents a moderate negative correlation.
PCI or Physical Capacity Index: This TIS PCI correlation coefficient also came to be at -0.370 and once again found to have a moderate negative correlation
P-Value:

The p-value on the correlation of SCS and TIS is at 0.001. This is less than the common alpha level at 0.05, therefore a statistically significant correlation is reported. This means that there is strong evidence for rejecting the null hypothesis that there is no correlation between the two variables in the study. Similar is the case with the P value of the correlation of TIS and PCI that has been calculated as 0.001, which simply shows that this correlation is also statistically significant.
df: Degrees of Freedom:

df in both correlations has been calculated as 70. As a general definition, degrees of freedom describe the number of data
points utilized for the calculation of correlation and it influences the tests in terms of the power to detect an effect, the smaller the
degree of freedom the lesser the statistical power and the larger the statistical power with the higher degrees of freedom.
SCS and TIS: There is a moderate negative correlation between SCS and TIS at -0.370. Thus, the more the value for core muscle stability (SCS), the lesser would be the value
for trunk impairment (TIS). According to your hypothesis that there exists a positive association of core stability with the overall control of the trunk.
TIS and PCI; trunk control: TIS shows correlation = -0.370 to physical capacity: PCI trunk control: bigger it gets, the better the individual's physical capacity.

4.2.3 simple linear Regression analysis of core muscle stability and trunk control.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101.282	1	101.282	12.233	.001[b]
	Residual	587.841	71	8.279		
	Total	689.123	72			

a. Dependent Variable: TIS

b. Predictors: (Constant), SCS

Table 10 simple linear regression analysis of core muscle stability and trunk control

ANOVA Table Interpretation

Model: This line is the regression model where SCS is the predictor variable.

Sum of Squares: Regression (101.282): This value is the variation in TIS that

is explained by the

predictor, SCS. The higher the value, the more variance explained by the model in the dependent variable.

Residual (587.841):

This is the portion of TIS variation which the model could not account for. This is either an error or unaccounted variance.

Total (689.123):

It isthe sum of residual and regression sum of squares. This means it gives the tot al variation in dependent variable, TIS

Degrees of Freedom (df):

Regression (1) : This implies that this model has one predictor, SCS.

Residual (71): This is obtained by subtracting the number of predictors minus 1 from the total observations, that is, n - k - 1. Here, you have a total of 72 observations as indicated by your total df = 72.

Total (72): It is the total observation minus 1.

Mean Square:

Regression Mean Square (101.282): This is the sum of squares for regression divided by the degrees of freedom for regression that is 101.282/1.

Residual Mean Square (8.279): This is the sum of squares for residual divided by the degrees of freedom for residual that is 587.841/71.

F-value (12.233):

The F-value is the quotient of the mean square of regression and the mean square of residuals. It tests how significant the model is for the overall variance. Thus, the higher the value of F, the more will be the variance explained compared to the residuals.

Sig.: The p-value is equal to 0.001. This means that the result is highly significant for a regression model. Its value being less than.05 indicates a predictor significantly influencing the dependent variable here

being SCS. In other words, evidence overwhelmingly goes in favor of the assumption that trunk control is well associated with core muscle stability.

4.2.3.0 Histogram of core muscle stability and trunk control impairment

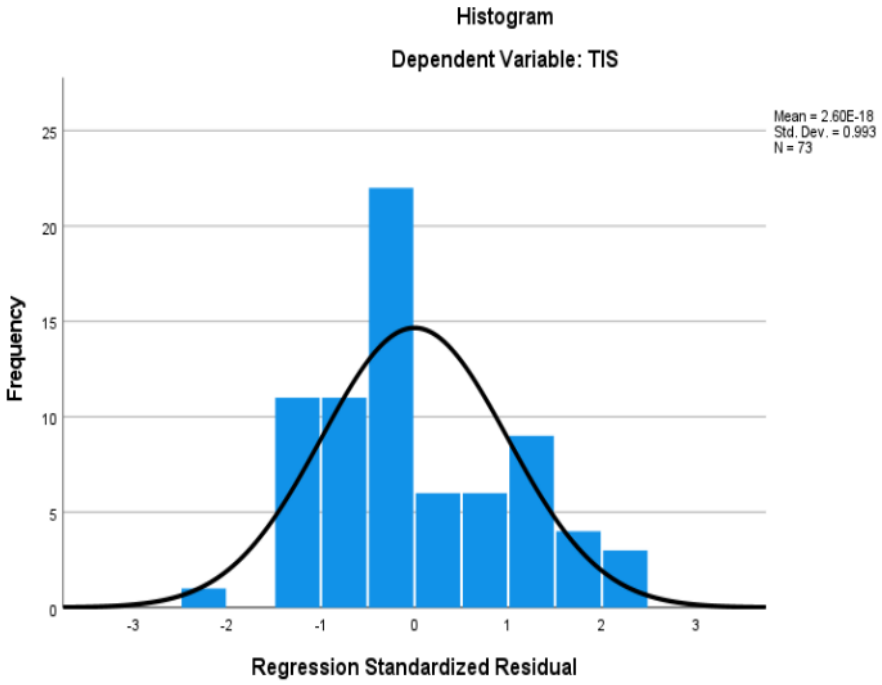

Figure 8 Histogram of core muscle stability and trunk control impairment

4.2.4 Simple linear regression analysis of core muscle stability and energy cost of walking

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.204	1	3.204	13.560	.000[b]
	Residual	16.773	71	.236		
	Total	19.977	72			

a. Dependent Variable: PCI

b. Predictors: (Constant), SCS

Table 11 simple linear regression analysis of core muscle stability and energy cost of walking

Model:
This is a row for a regression model showing SCS as a predictor for PCI.
Sum of Squares:
Regression (3.204) It was the amount that had varied in
PCI contributed by being explained by this predictor.
A higher value, one nearing one revealed that this was an expression of explaining meaningful variance of the kind relevant to PCI variation. Residual (16.773), showed the unexplained and remained variation with PCI- the one that might be denoted as error with respect to the variation as well.
Total (19.977): This is the total variance in the dependent variable, PCI, or the sum of the regression and residual sums of squares.
Degrees of Freedom (df): Regression (1): You have one predictor variable, SCS, in your model.

Residual (71): This is calculated as total number of observations minus number of predictors minus 1, or n - k - 1. In this case you have 72 total observations.
Total (72): The sum of all observations minus 1.
Mean Square:
Regression Mean Square (3.204): This is the sum of squares for regression divided by its degrees of freedom (3.204 / 1).
Residual Mean Square (0.236): This is the sum of squares for residual divided by its degrees of freedom (16.773 / 71).
F-value (13.560): F Value is a ratio of Mean Square for regression to that of Residuals; in other words, it presents the value of overall importance of the model. As F-values are higher in comparison with the residuals model explains substantial variance.
P-value Significance (Sig.): The p-value of 0.000 shows the significance of the regression model. Since this value is much less than 0.05, it indicates that the predictor, SCS, significantly predicts the dependent variable, PCI.
This gives strong evidence that core muscle stability is related to physical capacity.

4.2.4.0 Histogram f core muscle stability and physiological cost of index (energy cost of walking)

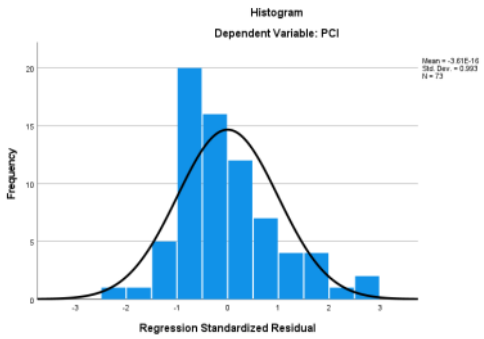

Figure 9 Histogram of core muscle stability and energy cost of waking

4.2.5 Comparison Between Trunk Control and Energy Cost of Walking.

4.2.5.0 Correlation analysis of trunk control and energy cost of walking

Correlations

			TIS	PCI
Spearman's rho	TIS	Correlation Coefficient	1.000	-.491**
		Sig. (2-tailed)	.	.000
		N	73	73
	PCI	Correlation Coefficient	-.491**	1.000
		Sig. (2-tailed)	.000	.
		N	73	73

**. Correlation is significant at the 0.01 level (2-tailed).

Table 12 Correlation analysis of trunk control and energy cost of walking.

This Spearman's rank correlation analysis focuses on the relationship between TIS and PCI. Below are the results, grouped by:
Correlation Coefficient (-0.491): The correlation coefficient of TIS with PCI was -0.491. The negative correlation was moderate. In other words, it indicates that as the score on TIS increases or in other words better trunk control, the values for PCI would be smaller in this context, and hence less energy expenditure in walking; otherwise, the case may be opposite.
Significance Level (0.000): The p-value for this correlation is 0.000, a lot less than the chosen significance level of 0.01. This signifies that the correlation is very statistically significant at the confidence level of 99%. For all practical purposes, this means that there is very good reason to believe this negative correlation did not come by chance.
Interpretation A strong moderate negative correlation would imply that the higher the scores for trunk control, in the form of higher TIS, the lower would be the energy cost of walking, as represented by lower PCI, among your sample of 73 subjects. Such a finding would lend credence to ideas that involvement

of trunk stability might be useful in mitigating energy expenditure in walking, and this is pertinent to stroke rehabilitation settings.

4.2.5.1 Multiple Regression Analysis of trunk control impairment and energy cost of walking

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.356	1	4.356	19.801	.000[b]
	Residual	15.621	71	.220		
	Total	19.977	72			

a. Dependent Variable: PCI

b. Predictors: (Constant), TIS

Table 13 regression analysis of trunk control impairment and energy cost of walking.

This ANOVA table indicates the significance of the overall regression model used in predicting PCI based on TIS scores.
All parts are explained as shown below:
Regression Sum of Squares (4.356): This means by how much variance in dependent variable PCI can be described using independent variable TIS.
Residual Sum of Squares (15.621): This is the portion of the variance in PCI that the TIS explained inadequately.
Total Sum of Squares 19.977: These are the total variances in PCI, being cumulative from the regression and the residual sums of squares.
F-value: 19.801- An F-value is the ratio of the mean regression sum of squares and mean residual sum of squares. A high F-value implies that the model robustly predicts PCI.
Sig. = 0.000: the p-value is 0.000, which is far below the standard level of significance, 0.05. This shows that the model is statistically significant. Hence, TIS statistically predicts PCI and is highly unlikely to have occurred by chance.

4.2.5.2 Histogram of trunk control impairment and energy cost of walking

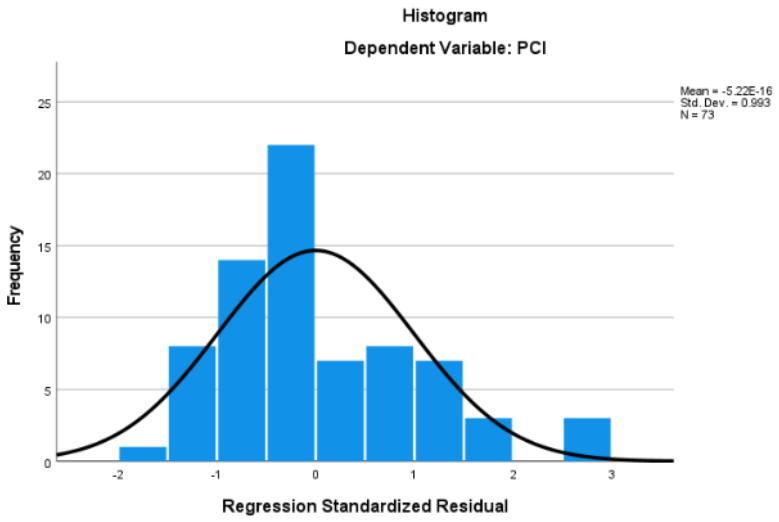

Figure 10 histogram of trunk control impairment and energy cost of walking.

4.2.6 Multivariate analysis of core muscle stability impact on trunk control impairment and energy cost of walking.

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.912	342.340[b]	2.000	66.000	.000
	Wilks' Lambda	.088	342.340[b]	2.000	66.000	.000
	Hotelling's Trace	10.374	342.340[b]	2.000	66.000	.000
	Roy's Largest Root	10.374	342.340[b]	2.000	66.000	.000
SCS	Pillai's Trace	.363	2.969	10.000	134.000	.002
	Wilks' Lambda	.655	3.110[b]	10.000	132.000	.001

	Hotelling's Trace	.500	3.248	10.000	130.000	.001
	Roy's Largest Root	.438	5.867[c]	5.000	67.000	.000

a. Design: Intercept + SCS

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 14 Multivariate analysis of core muscle stability impact on trunk control impairment and energy cost of walking.

The Multivariate Tests table reports the results of several tests to determine whether the predictor variable, which I have called SCS-here likely Strength of Core Stability- affects a vector of multiple dependent variables. Each test (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) makes a different conclusion about the effect. Let's go through how to read these outputs:

Reading Multivariate Test Results
Reading Intercept Results:

Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root all have very high F-values at 342.340 with p-values of.000. This simply means that the dependent variables are statistically significantly different on a baseline level without any influence from SCS.
Effect of SCS (Core Stability Strength):

Pillai's Trace (Value = 0.363, F = 2.969, p =.002): At a p-value of.002, Pillai's Trace is significant and, therefore, SCS has a significant effect on the combined dependent variables at the multivariate level. An effect size value of Pillai's Trace = 0.363 would mean moderate effect size.
A large p-value of.001 here also ends with the fact that SCS had a significant impact on the overall dependent variables. The Wilks' Lambda value at 0.655 supported the moderate effect.
Hotelling's Trace (Value = 0.500, F = 3.248, p =.001): Hotelling's Trace also agreed with the fact that there was a significant multivariate effect with a p-value of.001.
R - Largest Root (Value = 0.438, F = 5.867, p =.000): The Roy's Largest Root, which detects the largest effect, proved to be significant at a level of p

< 0.001 with a value of F = 5.867. By this test, it seems that the largest difference made by SCS among these dependent variables is strong as well as significant.

Interpretation Summary:

All four tests verify that SCS has an effect size of a certain magnitude to the combination of dependent variables, which in this study are trunk control impairment and energy cost of walking. The p values are below 0.05 for all tests performed. Thus, it was established that core muscle stability strength significantly impacts these outcome measures for your sample population. It is noted also that effect size values have moderate size, Pillai's Trace = 0.363, Wilks' Lambda = 0.655, and indicates a practically meaningful impact that core stability has on these measures.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	TIS	156.768[a]	5	31.354	3.946	.003
	PCI	4.987[b]	5	.997	4.459	.001
Intercept	TIS	3350.327	1	3350.327	421.658	.000
	PCI	16.301	1	16.301	72.863	.000
SCS	TIS	156.768	5	31.354	3.946	.003
	PCI	4.987	5	.997	4.459	.001
Error	TIS	532.356	67	7.946		
	PCI	14.989	67	.224		
Total	TIS	13235.000	73			
	PCI	66.569	73			
Corrected Total	TIS	689.123	72			
	PCI	19.977	72			

a. R Squared = .227 (Adjusted R Squared = .170)

b. R Squared = .250 (Adjusted R Squared = .194)

Table 15 Test of between subject effect

Model Fit:
For TIS: The model explained about 22.7% of the variance, with an adjusted R^2 of.170, indicating a weak fit.
For PCI: The model explained about 25.0% of the variance, with an adjusted R^2 of.194, showing slightly stronger explanatory power compared to TIS.

Corrected Model:
The model had a large effect on both TIS ($F = 3.946$, $p = .003$) and PCI ($F = 4.459$, $p = .001$). This would indicate that SCS greatly contributes to the variations both in trunk impairment and in postural control.

Intercept:
Intercept is highly significant for both TIS $F = 421.658$, $p < .001$ and PCI $F = 72.863$, $p < .001$. That significance means a baseline of TIS and PCI at significantly different levels from zero.
Effects of SCS (Core Stability)
There was a significant effect on TIS scores due to the effects of core stability ($F = 3.946$, $p = .003$), which meant that more stable cores increased trunk control.
For PCI: Another factor that heavily impacts core stability is PCI ($F = 4.459$, $p = .001$) indicating the possibility that improved core stability has an impact on improved postural control in the stroke patients.

Error Terms:
The mean square error for TIS is 7.946, and for PCI, it is.224. These values represent the unexplained variances of TIS and PCI, and it means that there is still some variability not explained by the model, especially TIS.

Conclusion:
Based on the analysis, core stability (SCS) has a significant statistical impact on trunk control (TIS) and postural control (PCI) in stroke patients. Such notable F-values and low p-values indicated that enhancements of core stability might positively be contributing to the trunk as well as postural control, thus supporting the role of core-focused interventions during rehabilitation. Although the

model explained a modest amount of variance, these findings elaborated the role of core stability in improving functional outcomes from stroke rehabilitation.

Chapter 05

Discussion

5.0 Introduction to Findings

1. Demographic Characteristics of Participants

Age and gender distribution: The study involved 73 participants aged 20 to 80 years, with a mean age of 59.5, predominantly older adults commonly affected by strokes. The gender distribution showed a slight imbalance, with males at 46.8% and females at 35.2%, reflecting broader population trends in stroke incidence. Most participants were in the chronic phase of recovery, with 53.1% experiencing left-side hemiplegia and 46.9% right-side hemiplegia, indicating a balanced representation of both conditions. Additionally, 33.8% had comorbidities, primarily hypertension and diabetes, which can complicate rehabilitation efforts. This diverse demographic underscores the need for integrated assessments of core stability, trunk control, and walking costs during stroke recovery, emphasizing the importance of personalized rehabilitation strategies that address both stroke-related impairments and comorbid health issues.

Ethnicity: This sample consisted only of Muslims, which therefore suggests ethnic and religious homogeneity. This could be attributed to the dominant population of the region where the study took place, thus making all the respondents culturally uniform.

Occupational Status: Manual Labor: The largest proportion was manual laborers, with a total of 61.6% (45 patients) working in highly physically demanding jobs. This category of patients would probably be more demanding in their daily lives, which could influence recovery and rehabilitation.
Professional: The lowest was professional (13.7% or 10 patients) from the professions like education or health sectors. These patients could be quite different in terms of their physical activity and functional demand from the manual laborers.
Housewives: Around 20.5% were housewives and practiced moderate physical activities. Rehabilitation goals for

this subgroup might include enhanced mobility and greater self-efficacy for the accomplishment of daily activities.
Sedentary Lifestyle: Only 4.1% or 3 persons had a sedentary lifestyle, a special rehabilitation requirement with low baseline level of physical fitness.

2. Statistical Results on Core Stability Measures

Core Stability Scores (SCS):
Range: The scores ranged between 1 and 6, while the mean was 3.97; thus, core stability among the respondents was moderately rated.
Standard Error: At 0.151, it reflects that the mean score is a good estimate of the population.
Variance: A variance of 1.666 reflects a moderate spread of scores on both sides of the mean.
Static Sitting Balance (SSB):
Range: Scores ranged between 2 and 7 with a mean of 6.42; thus, the respondents did well without support in static balance.
Standard Deviation and Variance: Low values indicate that participants were relatively consistent in their performance.
Dynamic Sitting Balance (DSB):
Range: Scores ranged from 0 to 10 with a mean of 3.86, which indicates lower performance than SSB.
Standard Deviation and Variance: High scores range indicates large differences in participants' dynamic balance.
2. Coordination:
Range: Scores between 0 and 6 with a mean of 2.85 indicate that participants had moderate coordination.
Standard Deviation and Variance: Moderate spreading around the mean indicates variations in coordination skills.
Trunk Impairment Scale (TIS):
Range: Scores from 7 to 21, with mean 13.11 with moderate trunk control capacity across participants.
Standard Deviation and Variance: Large variance 9.571 indicates wide range of variability in trunk control skills

3. Physiological Cost Index (PCI)

Mean PCI: The mean of PCI score was 0.7989, hence moderate energy cost for walk.
Median and Mode: The median (0.6600) is less than the

mean, hence most the participants had a lower to average PCI value.
SD and Variance: SD is moderate indicating that a variation exists for the mean energy cost for walking among the participants.

4. Results of Correlation

Stability of the Core and Trunk Control: It has been shown that a moderate negative correlation (-0.370) exists between SCS and
TIS, hence there is more trunk impairment, the better the core stability.
Trunk Control and PCI: A similar association (-0.370) between TIS and PCI indicates that improved trunk
control is associated with reduced metabolic costs of walking.
Statistical Significance: Both were statistically significant ($p < 0.001$). This validates the assumption of the study that core stability is positively related to trunk control.

5. ANOVA and Regression Analysis

Multiple Regression Analysis for TIS: The model explained 22.7% variance in TIS with the F-value being significant: 12.233 with p-value: 0.001, which confirms that core stability is indeed a meaningful predictor of trunk control.

Multiple Regression Analysis for PCI: The model explained 25.0% variance in PCI. The F-value was statistically significant: 13.560 with p-value being 0.000 underlines the relationship between the core stability and physical capacity.

Multivariate Tests

Effect of Core Stability on Multiple Dependent Variables: Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root all demonstrated an effect of core stability on impairment of trunk control and energy cost of walking.
Effect Size: The moderate effect size values indicate a practically meaningful effect of core stability on these outcome measures.

Conclusion

Overall, in general, research suggest that core stability can have an influence on trunk control post-stroke as well as energy cost of walking.

cost while walking. Despite the two models accounting for small variances, results draw focus to the role and requirement of core-focused approaches for rehabilitation purposes. Potential betterment of core stability as an approach toward obtaining better outcomes in rehabilitation in improving better control of the trunk and further reducing energy costs during walking may prove effective for rehabilitation of such patients.

5.1 Comparison with previous studies

General Impact of Core Stability on Trunk Control and Gait in Stroke Survivors: Studies indicate that core stability training is integral in stroke rehabilitation. It has been proven that core-stability exercises enhance trunk performance, balance, and gait, which are the main aspects affected by a stroke. For instance, a randomized controlled trial of core-stability exercises performed with the guidance of a tele rehabilitation app indicated that chronic stroke patients benefited significantly in terms of trunk control and sitting balance. However, gait was less improved. This study establishes the need for targeted trunk exercises as an adjunct to traditional therapy.

5.2 Stroke rehabilitation implications: Core-focused rehabilitation programs.

Based on the proven association of core stability to trunk control, core exercise programs, specifically designed exercises to enhance strengthening of muscles in this region, will enhance stability, posture, and lower the chances of falls in stroke victims.

Customized interventions based on hemiplegia: The high number of participants with either left- or right-side hemiplegia suggests that exercises targeting the core should be customized to the side of impairment of the patient to enhance symmetry and stability.

Energy Efficiency in Walking: Since enhanced trunk control has been associated with a lower PCI, core training would prove to improve walking efficiency by letting patients waste fewer calories in movements, thereby going further to enable independence and endurance in daily activities.

The inclusion of multivariate analysis in rehab programs, as used in your study, may be applied in tailoring rehabilitation approaches tailored to individua l performance metrics; this can help boost the recovery timeline and the effectiveness of the outcomes.
Integrating Coordination and Dynamic Balance Training: There was variability among participants based on dynamic sitting balance, and coordination, which allows for further improvements to include exercises for dynamic control; enhancing trunk stability and functional mobility.

5.3 Limitations of the Study

Sample Size and Demographic Homogeneity:
Sample size is 73 and informative, but not significant enough to generate generalized results that can apply across the different types of diverse populations. Sample is ethnically and religiously homogenous; in this study, it is limited to Muslims. Such restriction may limit applicability towards diverse cultures that may live lifestyles and may have variations in rehabilitation.
Gender imbalance:
The gender distribution is also slightly imbalanced with fewer females (35.2%). Since stroke impact and recovery patterns are believed to vary by gender, a better-balanced sample may allow for gender-specific rehabilitation needs.

Chronic Phase Restriction:
Participants were largely in the chronic phase of stroke recovery; thus, the findings are not as relevant for those in the acute or subacute stages. The various phases of recovery may produce distinct patterns of progression with regard to these phases influencing the relationship between core stability, trunk control, and energy cost in earlier phases.
No Baseline Measures of Physical Fitness

Details regarding baseline physical fitness, more so in subjects whose employment involved strenuous labor were n ot provided. Subjects in laboring jobs are inherently stronger in their cores that

might affect the outcomes rendering it difficult to ascertain effects of stroke on core stability and trunk control.
Only few functional measures:

There only is a mention of the core stability, trunk control, and energy cost of the study without other relevant functional outcomes such as quality of gait, falls risk, or participation during daily activities. This incorporation of these may help give more holistic views of rehabilitation need.
Lack of long-term data:

This cross-sectional study captures a single time point and, therefore, does not give insight into the development of core stability and trunk control over time. A longitudinal approach would be more effective in determining how core stability improvements affect walking efficiency and balance over time.
Variability in Rehabilitation Background:

Participants may have different backgrounds of prior rehabilitation that may influence their core stability and trunk control. Standardizing or documenting prior rehabilitation history would provide more controlled data.

5.4 Recommendations for Future Research

Future studies should increase the heterogeneity and diversity of the sample pop ulation by using participants from different ethnic, religious, and lifestyle backgrounds. This will increase generalizability of the outcomes. Studies with balanced gender representation would help identify gender-related differences in core stability and trunk control, so gender-specific rehabilitation plans may be developed. Including patients at all stroke phases, from acute through subacute and chronic stages, would give a glimpse into how recovery needs may differ at various stages to make interventions more individualized. B aseline fitness and occupational demands may also better explain how these influence the outcomes, thus tailoring rehabilitation.
Expanding assessment to include functional outcomes, such as gait quality, fall risk, and activity participation, could further give a holistic understanding of patient progress toward independence. Such longitudinal studies, which would record these variables over time, would be better able to capture the dynamic nature of recovery, guiding sustained interventions for

core stability and trunk control. Finally, previous rehabilitation backgrounds should be standardized to ensure consistent data are available, allowing researchers to accurately assess the effectiveness of core stability exercises in stroke recovery. Together, all these recommendations underscore the personalized, comprehensive, and stage-specific approaches in stroke rehabilitation.

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